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Optimizing education primary selection in universities: A fuzzy inference system with the mamdani method

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Abstract

Pemilihan jurusan pendidikan yang tepat sangat penting untuk perencanaan karir, terutama bagi calon-calon guru. Keputusan pemilihan jurusan ini seringkali sulit diambil karena berbagai faktor yang kompleks. Penelitian ini bertujuan untuk mengembangkan Fuzzy Inference System (FIS) dengan metode Mamdani untuk membantu calon mahasiswa guru di universitas pendidikan dalam memilih jurusan yang sesuai. Pengembangan sistem FIS menggunakan metode RAD (Rapid Application Development). Kriteria yang digunakan untuk pengolahan data melalui FIS meliputi nilai CBT pada tahun 2023, kapasitas jurusan, dan minat mahasiswa pada tahun 2022 khusus dalam kelompok SAINTEK di Indonesia. Mamdani digunakan untuk memberikan rekomendasi berdasarkan data calon mahasiswa terkait kemampuan kognitif, literasi bahasa, dan penalaran matematis. Hasilnya menunjukkan bahwa sistem ini dapat digunakan dalam membimbing calon mahasiswa saintek dalam memilih jurusan yang sesuai dengan minat dan potensi mereka. Penelitian ini secara khusus memberikan manfaat bagi calon mahasiswa SAINTEK yang ingin melanjutkan pendidikan ke perguruan tinggi di universitas-universitas pendidikan di Indonesia, dengan memberikan panduan yang terstruktur dan sistematis untuk pemilihan jurusan.

Choosing the right education major is very important for career planning, especially for prospective teachers. Choosing a major is often challenging due to various complex factors. This research aims to develop a Fuzzy Inference System (FIS) using the Mamdani method to help prospective student teachers at educational universities choose an appropriate major. FIS system development uses the RAD (Rapid Application Development) method. The criteria used for data processing through FIS include CBT scores in 2023, department capacity, and student interest in 2022, specifically in the SAINTEK group in Indonesia. Mamdani provides recommendations based on prospective student data regarding cognitive abilities, language literacy, and mathematical reasoning. The results show that this system can guide prospective science and technology students in choosing majors that suit their interests and potential. This research provides explicit benefits for prospective SAINTEK students who wish to continue their education at tertiary institutions at educational universities in Indonesia by providing structured and systematic guidance for selecting majors.

Keywords: Major selection, Fuzzy inference system, Mamdani method.

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INTRODUCTION

Choosing a major is one of the crucial decisions for students pursuing higher education (Mwantimwa, 2021). Selecting the right major will impact academic success and future career prospects (Aryani & Umar, 2020). However, this decision is often difficult due to various complex factors, such as interests, talents, abilities, job prospects, and economic conditions (Muriithi et al., 2021).

Saintek group, commonly known as the "SAINTEK" group, is a category of study programs or majors that focus on science and technology. This includes subjects and STEM groups such as math, physics, chemistry, biology, medicine, engineering, etc. When choosing a major in college, students can choose between the Saintek and Soshum groups, depending on their interests and talents (Prayitno, 2023). Saintek includes majors such as medicine, engineering, and mathematics, while Soshum focuses more on social sciences and humanities. This difference allows students to choose an educational path according to their interests (Maharani et al., 2021). In order to avoid multiple interpretations of this research, Saintek groups were mentioned as STEM groups.

Many things need to be considered when deciding on a major (Yuliana et al., 2022). Most people choose majors that are easy to handle and have potential in the job market without considering their interests and abilities (Lent & Brown, 2020). However, it is essential for prospective students who will pursue higher education to reconsider this opinion. Making the wrong decision will significantly affect their future (Febrianti et al., 2020) (Syaharuddin et al., 2019). The apparent impact is that students will not enjoy the learning process and will experience failure in their studies (Mulyani et al., 2018). Therefore, a quality decision support system can declare, support, and enhance individual achievements and ensure that all students receive a fair evaluation, not limit students' current and prospects.

Meanwhile, traditional methods used in significant selection, such as psychological tests and consultations with guidance counsellors, also have limitations (Keller-Schneider et al., 2020). These methods rely on subjective perceptions and often fail to depict students' interests and abilities accurately (Resti & Resti, 2019). To assist students in making such decisions, various decision support systems (DSS) have been developed, one of which is the fuzzy inference system (FIS) using the Mamdani method (Pourjavad & Mayorga, 2017) (Rizdania, 2021). This method can map complex and uncertain decisions into a form more accessible for humans to understand (Sridharan, 2021).

Teachers or educators are one of the factors determining the success of every educational effort (Sun et al., 2008). Educational efforts to improve the quality of human resources always boil down to the teacher factor (Laili, 2020). Qualified prospective teacher students will produce quality human resources in the future (Akhyar, 2019). In order to get prospective student teachers with the abilities and competencies that match their interests and talents, a decision support system described previously is needed. In this regard, the Science, Technology, Engineering, and Mathematics (STEM) group offers significant options in teacher education universities in Indonesia. Therefore, optimizing the decision support system is essential to help prospective education students choose a department/major that suits their interests and abilities.

In previous studies, fuzzy logic has been used in various fields as a decision support system. In the case of decision-making, fuzzy logic is used as a decision-making tool based on predetermined rules (Rifanti et al., 2023). Therefore, this research will develop an application for a decision support system based on the fuzzy inference system with the Mamdani method for optimizing primary selection in universities for teacher education. This app can provide significant recommendations for the STEM group based on their profiles and preferences, maximizing their academic potential and educational career prospects.

METHODS

In this research, the Fuzzy Inference System was developed by adapting the Rapid Application Development (RAD) methodology, which consists of four stages: requirements planning, prototype design, and iterative construction (Gabriel et al., 2023)—at the same time, developing the Fuzzy Inference System using the Mamdani method. The Fuzzy Mamdani method for computing control outputs involves three main parts, according to (Pourjavad & Mayorga, 2017), such as fuzzification, evaluation, and defuzzification.

Planning Phase

The requirements planning stage begins with the first stage of Mamdani, namely the Fuzzification stage, which determines the input and output variables along with their corresponding fuzzy sets. The Mamdani method divides the input and output variables into one or more fuzzy sets. Secondly, Rule Evaluation encompasses the implication function using MIN and rule composition. In this stage, the implication function employed is MIN, and the rule composition is obtained through the inference process in the Mamdani method. The max method is utilized among the three inference methods available (max, additive, and probabilistic OR). Lastly, the Defuzzification stage involves using the centroid of area (COA) method for defuzzification in Mamdani's fuzzy rule composition. This process can be represented by the following Equation (1).

$$z = \frac{\sum \mu D}{\sum \mu} \quad (1)$$

where μ is the membership degree of the fuzzy set, and D is a crisp number.

The selection of majors at the Teacher Education Universities for prospective students in the STEM group in this research is based on the reference of admission results announced from the UTBK in 2022 and the Schoolfess application. UTBK (Ujian et al.) is a computer-based written test administered by the Lembaga Tes Masuk Perguruan Tinggi (LTMPT) to prospective education students who want to enrol in state universities in Indonesia. Based on the National Selection for New Student Admissions (SNPMB) to determine the appropriate major, students will be evaluated based on UTBK-related subjects: cognitive abilities, proficiency in Indonesian and English, and mathematical reasoning abilities. So, the development of FIS Mamdani will use variables or criteria from cognitive abilities, literacy in Indonesian and English, and mathematical reasoning.

The output variable consists of four choices of majors in the STEM group at Teacher Education Universities in Indonesia and no recommendations. The selection of majors is classified into three categories: Engineering (FT), Mathematics and Natural Sciences Education (FMIPA), and Sports Science (FIK). A range of criteria values is required to build the fuzzy inference system (FIS), which will be used as data in the calculation. However, each category used to classify student primary selection has different provisions based on the provisions set out in the source references. Therefore, we must first understand the ranges' provisions for the three variables, including determining the category of student primary selection. Table 1 below shows the range of criteria values used.

In this research, the optimization of decision support systems using the fuzzy Mamdani method. It is hoped that in this study, the system can work to make decisions according to predetermined criteria.

Table 1. Quantities of criteria

Parameter	Criteria	Code	Range
Input	Cognitive Ability	K1	0 – 1000
	Language Literacy	K2	
	Mathematical Reasoning	K3	
Output	Recommendation Major for STEM Group	Jurusan	0 – 1000

Prototype Design

In the prototype design phase, the assessment for each criterion was defined into three, namely high, medium, and low, with different value ranges adapted based on the schoolfest scores and compared with the number of participants who registered with the capacity accepted by the UniversityUniversity. The range of values for the three criteria is presented in Table 2. These range values are then used as data to determine recommendations for college majors/fields of study.

Iterative Construction

At the prototype construction stage, the main component display of the Mamdani fuzzy inference system (FIS) was implemented by paying attention to the four functional modules that make up the system such as fuzzification, inference, rules, and defuzzification which can be seen in Figure 1.

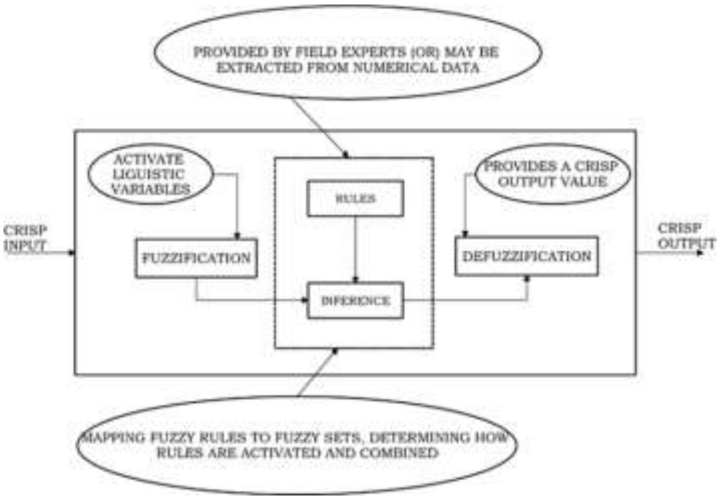

Figure 1. Diagram of the Mamdani FIS

Figure 2 represents the general structure of the fuzzy inference system in this research, when this architecture always flows from left end to right end, from three inputs (K1, K2, and K3) to output (Recommendation Major for STEM Group).

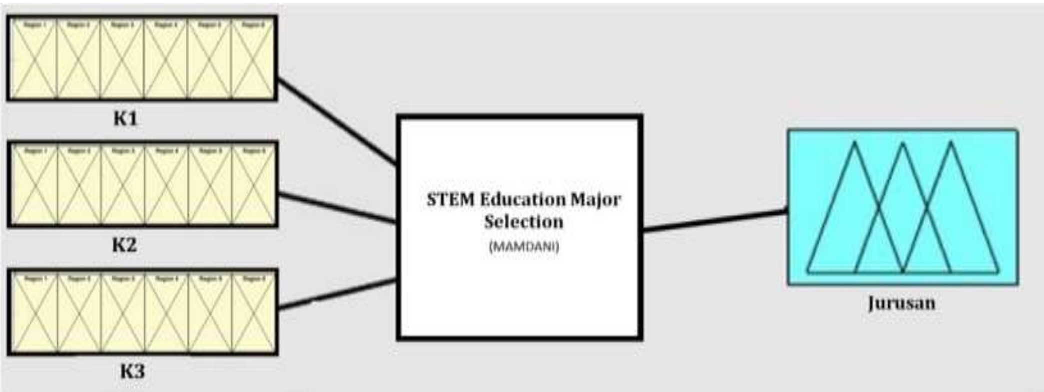

Figure 2. Diagram of the Mamdani FIS

RESULT AND DISCUSSION

The fuzzy system was developed using the Mamdani method by considering the functional module shown in Figure 1, which contains the stages of fuzzification, inference, rules, and defuzzification.

Fuzzification

Fuzzy Logic (FL) is utilized to process real-time experimental inputs and determine their degree of membership (Sridharan, 2021). Fuzzification is a part of FL, which involves converting crisp values into fuzzy values from 0 to 1 (Zadeh, 1965). In this context, a value of 1 represents absolute membership (100%), while a value of 0 indicates no membership (0%) within the fuzzy set. Table 2 provides detailed information on the associated linguistic variables of each parameter, allowing for a comprehensive understanding of the fuzzy sets involved.

Table 2. Fuzzy linguistic variables for each parameter

Parameter	Code	Linguistic variable	Range	Representation
Input (3)	K1	High (T)	592 – 1000	Figure 3
		Medium (S)	(587). – 597	
		Low (R)	000 – 592	
	K2	High (T)	560 – 1000	Figure 4
		Medium (S)	(500). – 620	
		Low (R)	000 – 560	
	K3	High (T)	610 – 1000	Figure 5
		Medium (S)	(577). – 643	
		Low (R)	000 – 610	
Output	Jurusan	Mathematics and Natural Sciences Education (FMIPA)	572 – 1000	Figure 6
		Engineering (FT)	564 – 574	
		Sports Science (FIK)	(556). – 566	
		No Recommendations (No)	000 – 558	

Fuzzy inputs are necessary to utilize the Mamdani fuzzy inference system. To convert crisp inputs into fuzzy inputs, membership functions are employed to represent the fuzzy sets of the inputs. Table 2 provides various forms of membership functions that represent different levels of fuzziness in different situations.

Input variables for Cognitive Abilities (K1), Language Literacy (K2), and Mathematical Reasoning (K3)

The calculation of the range for each category is adjusted based on the Schoolfest score (https://schoolfess.id/skor-utbk?tahun=2023) and compared with the number of participants who register with the capacity accepted by the UniversityUniversity. Figures 3, 4, 5, and 6 represent fuzzy membership functions created using the Spreadsheet application. Based on these four figures, the results show membership functions that combine trapezoidal and triangular shapes. These membership functions are commonly used for simplicity, as they can be represented using straight lines (Seising, 2020) (Sukirno et al., 2020).

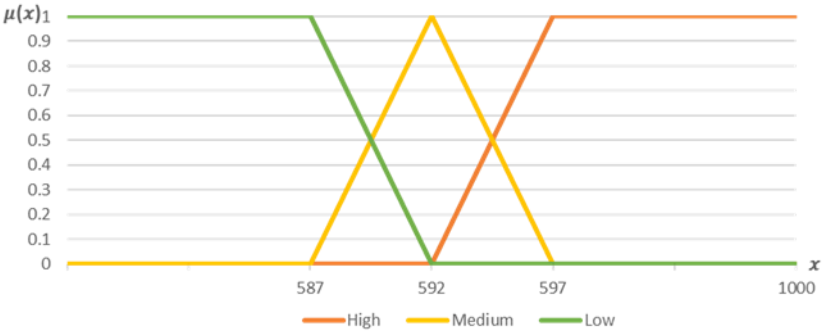

Figure 3. Membership Function Plots for Input K1

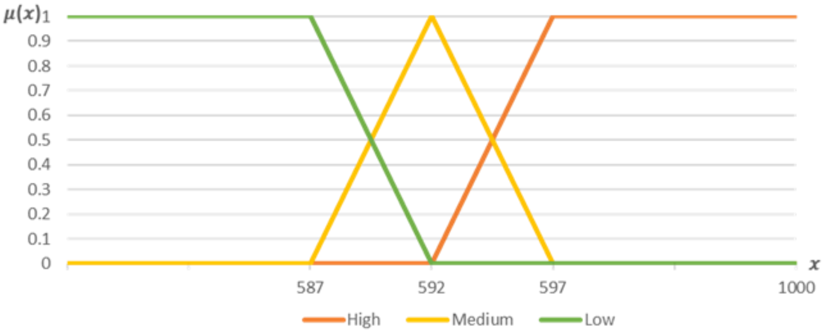

Figure 4. Membership Function Plots for Input K2

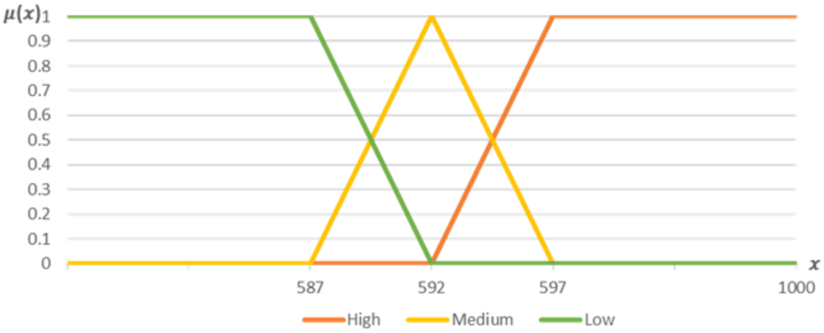

Figure 5. Membership Function Plots for Input K3

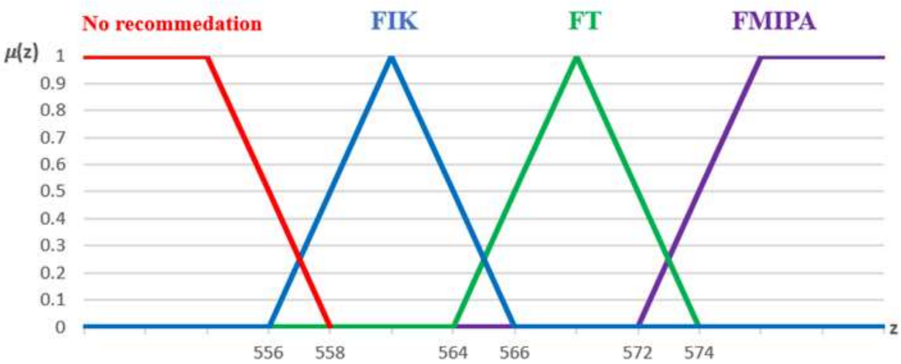

Figure 6. Membership Function Plots for Major Output

Referring to Figures 3, 4, and 5, the constructed inference system obtains the Fuzzy Decision Index input. The mathematical Equation for obtaining the fuzzy membership value of the input set for cognitive ability (K1) is divided into 3 (three) fuzzy sets, namely: high (K1T), medium (K1S), and low (K1R), shown in equations (2), (3) and (4) respectively as follows, with the x value being the UTBK material score for cognitive ability variable.

$$\mu_{K1\,T}(x) = \begin{cases} 1, & x \geq 597 \\ \dfrac{x-592}{5}, & 592 < x < 597 \\ 0, & x \leq 592 \end{cases} \tag{2}$$

$$\mu_{K1\,S}(x) = \begin{cases} 0, & x \leq 587 \text{ } or \text{ } x \geq 597 \\ \dfrac{x-587}{5}, & 587 < x < 592 \\ \dfrac{597-x}{5}, & 592 < x < 597 \\ 1, & x = 592 \end{cases} \tag{3}$$

$$\mu_{K1\,R}(x) = \begin{cases} 1, & x \leq 587 \\ \dfrac{592-x}{5}, & 587 < x < 592 \\ 0, & x \geq 592 \end{cases} \tag{4}$$

The mathematical Equation for obtaining the fuzzy membership value of the input set for language literacy (K2) is divided into 3 (three) fuzzy sets, namely: high (K2T), medium (K2S), and low (K2R), shown in equations (5), (6) and (7) respectively as follows, with the x value being the UTBK material score for language literacy variable.

$$\mu_{K2\,T}(x) = \begin{cases} 1, & x \geq 620 \\ \dfrac{x-560}{60}, & 560 < x < 620 \\ 0, & x \leq 560 \end{cases} \tag{5}$$

$$\mu_{K2\,S}(x) = \begin{cases} 0, & x \leq 500 \text{ } or \text{ } x \geq 620 \\ \dfrac{x-500}{60}, & 500 < x < 560 \\ \dfrac{620-x}{60}, & 560 < x < 620 \\ 1, & x = 560 \end{cases} \tag{6}$$

$$\mu_{K2\,R}(x) = \begin{cases} 1, & x \leq 500 \\ \dfrac{560-x}{60}, & 500 < x < 560 \\ 0, & x \geq 560 \end{cases} \tag{7}$$

Then, the mathematical Equation to obtain the fuzzy membership value of the input set for mathematical reasoning (K3) is divided into 3 (three) fuzzy sets, namely: high (K3T), medium (K3S), and low (K3R), presented respectively in equations (8), (9) and (10) as follows, with the x value being the UTBK material score for mathematical reasoning variable.

$$\mu_{K3\,T}(x) = \begin{cases} 1, & x \geq 643 \\ \frac{x-610}{33}, & 610 < x < 643 \\ 0, & x \leq 610 \end{cases} \quad (8)$$

1. $$\mu_{K3\,S}(x) = \begin{cases} 0, & x \leq 577 \text{ or } x \geq 643 \\ \frac{x-577}{33}, & 577 < x < 610 \\ \frac{643-x}{33}, & 610 < x < 643 \\ 1, & x = 610 \end{cases} \quad (9)$$

$$\mu_{K3\,R}(x) = \begin{cases} 1, & x \leq 577 \\ \frac{610-x}{33}, & 577 < x < 610 \\ 0, & x \geq 610 \end{cases} \quad (10)$$

Developing Fuzzy Rules Base

The "rule base" is the most critical component of the FIS model. These rules are typically easier to formulate in linguistic rather than numerical form and commonly take the form of "IF-THEN" rules, which can be easily implemented using fuzzy conditional statements. IF-THEN rules consist of two parts: the antecedent, which is compared to the inputs, and the consequent, which represents the result (Azeez et al., 2019). Activating all rules with a true premise contributes to the fuzzy conclusion set. The activation level of each rule depends on the degree of match between its antecedent and the input. This imprecise matching serves as a basis for interpolation between possible input states and aims to minimize the number of rules needed to define the input-output relationship. IF-THEN rules are crucial because they allow human expertise and knowledge to be represented through fuzzy rules. Various approaches, such as expert knowledge, expertise, and fuzzy models, can generate fuzzy rules.

During this step, we will define a set of fuzzy linguistic rules based on expert knowledge to implement our fuzzy ranking model. It is important to note that these rules are adopted according to the decision-maker's preferences, ensuring suitable recommendations for selecting majors. One of the additional admission requirements for all majors is a minimum or medium criterion of cognitive ability. By understanding these requirements, students in the STEM group can make more leisurely choices of majors based on the established criteria. Based on these conditions, the FIS system designed for this model is shown in Table 3.

Table 3. The Inference Rules Base

Rule No	IF			THEN
	K1	**K2**	**K3**	**Major**
1	High	High	High	FMIPA
2	High	High	Medium	FMIPA
3	High	High	Low	FIK
4	High	Medium	High	FMIPA
5	High	Medium	Medium	FMIPA
6	High	Medium	Low	FIK
7	High	Low	High	FT
8	High	Low	Medium	FT
9	High	Low	Low	FT
10	Medium	High	High	FT
⋮	⋮	⋮	⋮	⋮
⋮	⋮	⋮	⋮	⋮
27	Low	Low	Low	No Recommendation

Defuzzification

After the fuzzy inference process is completed, the defuzzification process is needed to convert the fuzzy output into crisp, easily understood values. Defuzzification is performed using various methods available in fuzzy logic, such as the centroid method, height method, mean-max method, and others (Bisht et al., 2018). In this problem, the centroid method (refer to Equation (1)) will obtain a crisp output value from the fuzzy output set generated through the previous fuzzy inference process. Thus, the z value is obtained using the centroid method at this stage.

As an output for the Science and Technology group majors, it consists of 4 (four) fuzzy sets, namely: Mathematics and Natural Sciences (FMIPA), Engineering (FT), Sports Science (FIK), and No Recommendation (NR). Based on the obtained crisp decision value, the percentage of the decision level will be recalculated to generate the Fuzzy Decision Index. Referring to Figure 6, the constructed inference system obtains the Fuzzy Decision Index output as follows (see Equation (11)).

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$$\mu_{FMIPA}(z) = \begin{cases} 1, & z \geq 576 \\ \dfrac{z-572}{4}, & 572 \leq z \leq 576 \\ 0, & z \leq 572 \end{cases}$$

$$\mu_{FIK}(z) = \begin{cases} 0, & z \leq 556 \; or \; x \geq 574 \\ \dfrac{z-556}{5}, & 556 \leq z < 561 \\ 1 \quad 1, & z = 561 \\ \dfrac{566-\mathrm{z}}{5}, & 561 < z \leq 566 \end{cases}$$

$$\mu_{FIK}(z) = \begin{cases} 0, & z \leq 556 \; or \; x \geq 566 \\ \dfrac{z-556}{5}, & 556 \leq z < 561 \\ 1 \quad 1, & z = 561 \\ \dfrac{566-\mathrm{z}}{5}, & 561 < z \leq 566 \end{cases}$$

$$\mu_{NR}(z) = \begin{cases} 1, & z \leq 554 \\ \dfrac{558-\mathrm{z}}{4}, & 554 \leq z \leq 558 \\ 0, & z \geq 558 \end{cases} \tag{11}$$

Implementation of the Mamdani FIS in Spreadsheets

The instrument comprises a primary spreadsheet and multiple auxiliary spreadsheets that interact with it. The primary spreadsheet provides a simulation of the selection process for STEM group majors at Teacher Education Universities in Indonesia. The secondary spreadsheets contain calculations that serve as data sources for the primary spreadsheet.

Figure 7. Simulation View

The implementation of the Mamdani FIS system is carried out using a spreadsheet application displayed in Figure 7. The implementation results in an application that provides recommendation outputs in a customized selection of majors based on input results. The developed application consists of inputs such as registration numbers, cognitive ability test scores, language literacy, and mathematical reasoning. This implementation will be performed on 30 other cases. The implementation is presented in Table 4. The subject data was obtained based on personal information regarding the cognitive abilities, language literacy, and mathematical reasoning of prospective students in the science and technology group. This information was used as input to determine recommendations for majors that are suitable for their interests and abilities.

Table 4. Implementation of Inference Rules Base

Subject	Input			Output Major
	K1	K2	K3	
S1	596	563	610	FMIPA
S2	663	596	567	FIK
S3	593	557	630	FT
S4	785	564	539	FIK
S5	600	498	599	FT
S6	745	462	704	FT
S7	749	727	558	FIK
S8	604	579	477	FIK
⋮	⋮	⋮	⋮	⋮
S27	540	555	582	No Recommendation
S28	595	587	610	FMIPA
S29	595	522	660	FT
S30	597	543	532	FIK

Discussion

A decision support system for choosing a college major involves various methods. Decision Support System (DSS) uses the Fuzzy Mamdani method in decision-making. This method is based on fuzzy logic, which allows for handling uncertainty and ambiguity in data. In education, fuzzy logic can help make scholarship decisions, determine accreditation scores, or select study programs (Budi & Rezi, 2021) (Rifanti et al., 2023). Mamdani DSS is also applied in selecting majors to help high school students (Turzhanska et al., 2022). Its advantage lies in processing fuzzy data to produce more contextualized decisions.

The system that uses the Mamdani fuzzy method in this research can be used to help prospective education students and the equivalent in the selection of STEM Education majors or fields of study in college; several stages are carried out to get the output, namely: (1) the fuzzification process is carried out to determine the input and output variables and their fuzzy sets, (2) inference process, which is to perform reasoning using fuzzy input and fuzzy rules that have been determined so as to produce fuzzy output, (3) determination of rule base composition, and (4) defuzzification.

In this context, the focus of developing applications that integrate Mamdani DSS is to produce applications that will facilitate and provide support for prospective education students in helping to optimize the selection of majors in universities based on the results obtained from their UTBK tests (cognitive abilities, language literacy, and mathematical reasoning) or UTBK trials while still in high school. In addition, this system can also help counselling teachers provide direction to high school students and recommendations for choosing majors in college.

Meanwhile, the assessment team for student candidate selection in educational universities, especially for the STEM groups, can adopt this system by redefining the rule base that will be used as a reference for the formation of the final decision. Through the advantages of fuzzy logic, the final score can be adjusted to the assessment team's policy by adding certain rules in fuzzy logic. After all the assessment rules are inputted into the Fuzzy Inference System menu of the spreadsheet application, the assessment team can get the output in the form of the appropriate major, as shown in Figure 7.

This research confirms that the Mamdani fuzzy inference system has great potential and effectiveness in integrating decision support systems (Rizdania, 2021)(Tundo & Mahardika, 2023). The results of this study demonstrate that the implementation of the fuzzy inference system using the Mamdani method can help prospective education students at teacher-training universities to STEM majors that align with their interests and potential as future teachers. Through the integration of this Mamdani FIS, it is expected that the system can serve as a reference for prospective education students in the STEM group to make informed decisions regarding their future majors. Furthermore, this developed system can also be used by the selection committee for new student admissions at Universities for Teacher Education to attract potential education students who meet the competencies set by the Indonesian government.

CONCLUSION

The decision support system for major selection in STEM groups using the Mamdani fuzzy inference system method can be utilized to make recommendation decisions for majors available at Teacher Education Universities for STEM, according to the certainty of calculations involving tested abilities to determine the priority order of majors that should be chosen. This decision support system also assists students in determining majors that align with their interests and abilities. The research contributes significantly to helping STEM group students who wish to continue their studies at teacher-training colleges to select the appropriate majors at teacher-training universities in Indonesia. This system is expected to provide a more structured and systematic guide in the major selection process for prospective students of teacher training universities.

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CONFLICTS OF INTEREST

The authors declare no conflict of interest regarding the publication of this manuscript. Additionally, the authors affirm that ethical considerations, including plagiarism, misconduct, data fabrication and falsification, double publication and submission, and redundancies, have been thoroughly addressed and complied with.

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AUTHOR CONTRIBUTIONS

This section has to describe each author's contributions,

Author One: Conceptualization, writing - original draft, editing, and visualization; **Author Two:** Writing - review & editing, formal analysis, methodology, Validation, and supervision.

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